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STUDIES IN MILK SECRETION VIII.

INFLUENCE OF AGE ON MILK AND BUTTER-FAT YIELD IN HOLSTEIN-FRIESIAN CATTLE.

This bulletin contains a study of Holstein-Friesian Advanced Registry milk yields and butter-fat percentages. Milk yield is shown to rise at an ever decreasing rate as the age of the cow increases until the age of maximum productivity is reached, from this age of maximum productivity the milk yield declines at an ever increasing rate as age advances. Butter-fat percentage is shown to decline slightly with age. These facts are used to determine the most favorable age at which to test for advanced registry entry.

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BULLETIN 293

STUDIES IN MILK SECRETION VIII.

On the Influence of Age on Milk Yield and Butter-Fat Percentage, as Determined from the 365 Day Records of Holstein-Friesian Cattle.*

By John W. Gowen.

SUMMARY

This paper presents a study of the relation of age to the milk yield and to the butter-fat percentage of Holstein-Friesian advanced registry cattle for the 365 day test.

Two thousand, five hundred and eighty-six records of complete year test are analyzed in this paper.

These records show that milk yield rises at an ever decreasing rate as the age of the cow increases until the age of maximum productivity is reached, from this age of maximum productivity the milk yield declines at an ever increasing rate as age increases.

The butter-fat percentage for these Holstein-Friesian cows declines slightly as the age of the cow advances. This decline on the average amounts to only 0.150 per cent. Considerable variation on either side of this mean rate of decline is shown by the records.

The advanced registries for the different associations of stock growers handling the pure breeds of dairy cattle have focused the attention of the milk producers on the well known fact that age plays a very considerable part in the milk yield of a cow during any given lactation. The advanced registry officials have realized the necessity of taking cognizance of this effect of age on milk yield in determining the requirements which must be met by a cow. At the time when these requirements

*Papers from the Biological Laboratory of the Maine Agricultural Experiment Station, No. 134.

for the advanced registries were drawn up little information was available as to what real changes were brought about in the cow's milk yield or butter-fat yield by the advancing age of the cow. In view of this lack of data the herd associations adopted an arbitrary standard. This standard called for the production by Holstein-Friesian cows of not less than 250.5 pounds of butter-fat for the 365 day period at two years old and for every day that she exceeds two years of age the requirement in butter-fat shall be increased one-tenth of a pound. This increased requirement of one-tenth of a pound of butter-fat daily for each day's increase in age shall continue till the requirement reaches 360 pounds at the age of five years after which no further increase shall be made. Such a standard is obviously a linear function, that is, the cow's possibilities of butter-fat production must commence at 250.5 pounds as a two year old and must go on increasing one-tenth of a pound each day, one uniform step up each day, until she is 5 years old when the cow is supposed to be at her maximum productivity.

One of the first investigations[1] undertaken as part of the animal husbandry investigations of the Maine Agricultural Experiment Station was a study of the relation of age to milk yield and butter-fat percentage. In these first studies it was shown that milk yield does not increase with age linearly as was assumed to be the case by the Registry Officials. The increase of milk yield with age was found to be a logarithmic function.

Since the time when this law was first determined the essential conclusion then drawn has been established for milk yields from a variety of dairy cattle under diverse conditions. The seven day milk yields of Jersey cows have been shown to have a logarithmic relation to age[2]. The milk yield of Ayrshire cows likewise follows the logarithmic law[3]. A pure bred herd

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[1]Pearl, Raymond. 1914. On the Law Relating milk flow to age in dairy cattle. Proc. Soc. Expt. Biol. and Med. Vol XII, pp. 18-19.

[2]Pearl, Raymond and Patterson, S. W. 1917. The Change of Milk Flow with age, as determined from seven day records of Jersey cattle. Annual Report of the Maine Agricultural Experiment Station for 1917. pp. 145-153.

[3]Pearl, Raymond and Miner, John Rice. 1919. Variation of Ayrshire Cows in the Quantity and Fat Content of their milk. Jour. Agric. Research, vol. XVII, No. 6, pp. 285-322.

of Jersey cows maintained under the condition of a good dairy farm follows the logarithmic law in their relation of milk yield to age[4]. The registry of merit Jerseys for their 365 day records have also been shown to change in their milk flow logarithmically with age[5].

The necessity for a knowledge of these logarithmic functions for the different breeds has been well illustrated by the work of this laboratory for without it no comparison of milk records made at different ages can legitimately be made either for the purpose of determining the value of different sires as shown by the milk yield of their daughters or for inheritance studies. Such studies have already been reported in part for the Jersey[6] and Guernsey[7] breeds and also for inheritance studies on crosses of dairy and beef breeds[8]. The purpose of this paper is to determine the relations of milk yield and butter-fat percentage to age for the 365 day records of another breed, the Holstein-Friesian. These studies have given us the knowledge necessary to determine the transmitting ability of Holstein-Friesian sires. These facts will be published in a later paper of this series.

The Holstein-Friesian association have collected in their advanced registry work a large number of 365 day records. These year records, volumes 18-28, have been used for a study of the constituents of the milk of Holstein-Friesian cows[9]. The

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[4]Gowen, John W. 1920. Studies in Milk Secretion. V. On the Variation and Correlation of Milk Secretion with Age. Genetics, vol. 5. 111-189.

[5]Pearl, Raymond, Gowen, John W. and Miner, John Rice. 1919. Studies in Milk Secretion VII. Transmitting Qualities of Jersey Sires for Milk Yield, Butter-fat Percentage and Butter-Fat. Annual report of the Maine Agricultural Experiment Station for 1919, pp. 89-204.

[6]Loc. cit.

[7]Gowen, John W. 1918. Report of Progress on Animal Husbandry Investigations in 1917. Annual Report of the Maine Agricultural Experiment Station for 1918, pp. 205-228.

1919. Report of Progress on Animal Husbandry Investigations in 1919. Annual Report of the Maine Agricultural Experiment Station for 1919. pp. 249-284.

[8]Gowen, John W. 1918. Studies in Inheritance of Certain Characters of Crosses between Dairy and Beef Breeds of Cattle. Jour. Agric. Research, vol. XV, No. 1, p. 1-57.

[9]Gowen, John W. 1919. Variations and Mode of Secretion of Milk Solids, Jour. Agric. Research, Vol. XVI, No. 3, p. 79-102.

present study includes besides these records those of volumes 28 and 29. One noticeable fact which appears in the study of these later records, is the advance in the mean age of the cows which are tested for 365 day records over that of the previous study.

These records are arranged alphabetically according to the names of the cows in the advanced registry. Such an arrangement gives no clue as to any relationship which may exist between the attributes age and yearly milk yield and age and yearly butter-fat percentage. The data have been rearranged in a correlation table to allow the determination of these relations.

Two thousand five hundred and eighty-six complete 365 day records of the milk yield and age, and butter-fat percentage and age were available for study.

These records range from an age of 1 year and 6 months—2 years to 15 years—15 years and 6 months. The milk productions range from 6000-7000 to 31000-32000 pounds for the year period. The butter-fat percentage ranges from 2.4-2.5 to 4.6-4.7 per cent. The size of the range obviously requires a grouping of the material into classes. These classes have been chosen as 6 months for age commencing at one year and 6 months. The class interval for milk yield was taken as 1000 pounds of milk commencing at 6000 pounds for the year. The class interval for the butter-fat percentage was chosen as 0.1 per cent.

The resulting correlation tables are shown in tables 1 and 3. Table 1 shows the association of milk yield with age and table 3 the association of butter-fat percentage with age.

The mean milk yield for this group of cows was 16233.6 pounds for the year period. The standard deviation or the amount which they varied was 4039.3 pounds and the coefficient of variation of the milk yield was 24.9. The mean age at which these cows were tested was 4.57 years. The standard deviation for the ages was 2.25 years and the coefficient of variation was 49.11. It will be noted that the milk yield is slightly higher than that published for the first group of these data[10] as taken from volumes 18-28 of the previous paper. The slight increase in milk yield no doubt comes from the slight increase in age of the cows tested in the later volumes.

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[10] Loc. cit.

TABLE 1.

Correlation Surface for the Variables Age at Commencement of Test and Milk Yield in 365 Days.

HOLSTEIN-FRIESIAN CATTLE.

Age at Commencement of Test

Milk Yield	1:6–2:0	2:0	2:6	3:0	3:6	4:0	4:6	5:0	5:6	6:0	6:6	7:0	7:6	8:0	8:6	9:0	9:6	10:0	10:6	11:0	11:6	12:0	12:6	13:0	13:6	14:0	14:6	15:0–15:6	
5000– 6000																													
6		1																											1
7	3	4	1																										8
8	6	9	3	1	1																								20
9	10	20	10	6	2	2																							50
10	6	39	24	9	10	6	1	2	1	2				1				1											102
11	11	67	38	13	16	8	8	5	2	2	2	2						1											175
12	13	62	28	10	24	14	10	10	6	2	3	1	5	2	1			1	2			1	1						196
13	7	79	42	35	21	18	19	14	11	7	5	6	4	1	4		1	1		1		1	1	1					279
14	6	45	31	26	24	20	22	19	16	8	8	3	6	3	5	4	2	6	1		1	1						1	258
15	4	44	39	18	23	12	22	16	9	11	14	10	7	5	5	6	5			1				1				1	253
16	3	37	26	20	28	22	19	25	19	13	8	8	4	8	3	4	1	4	2	2	1	2							259
17		30	26	16	21	22	18	29	13	20	7	10	1	6	6	4	3	2	3										237
18	1	18	11	20	18	13	14	22	17	16	8	8	1	8	6	1		1	2										185
19		8	7	10	14	12	9	10	14	14	12	8	4	5	6	6	1	2			1								143
20	1	4	7	4	9	6	13	7	7	10	14	4	5	2	6	6	1				1		1						108
21		3	1	7	5	6	9	6	8	5	2	8	5	5		1	3	1	2				1						78
22		5	2	3	5	6	4	2	10	9	4	5	5	4			3	2	1		1	1							72
23				2	5	2	4	4	4	6	5	2	2	3	3		1												43
24				3		3	4	2	2	2	4	3	1	4	2		2												32
25						1	2	2	5	3	2	2		1	1	2	2	1			1								25
26					1	1	1	2	2	2	3	2	4	1		1	1												21
27					1			5	1	3	1	2		3															16
28				1		1	1	2		1		1	1	1						2									11
29								1	1	1	1		2		1			1											8
30						1		1	1		1																		4
31												1			1														2
32000–33000																													
	71	475	296	204	228	176	180	186	149	137	104	86	57	63	50	35	26	24	13	6	6	6	4	2				2	2586

Observation of table 1 shows that there is a considerable relation of milk secretion to age. The correlation coefficient as deduced from these data is $+0.4332 \pm .0108$. The extreme skewness of the data tends to reduce the size of the correlation coefficient as compared to the true relationship which does exist. In view of this fact only slight dependence can be placed in its absolute value. However, since the true amount of relationship would be increased rather than decreased were the skewness removed, it follows that there is a distinctly significant association of milk secretion to age. As our object is not the amount of the correlation which exists between these variables age and milk yield but is the form and equation to the curve which describes the relation we need not pause longer on this phase of the subject.

Proceeding to the calculations of the mean milk production within the age groups as seen in table 1 we find the mean 365 day milk yields to be those shown in table 2.

TABLE 2.

Mean 365 Day Milk Yield of Holstein-Friesian Cows at Different Ages.

Age at Test	Mean milk Yield	Age at Test	Mean milk Yield
1 yr. 6 mo. to 1 yr. 11 mo.	12007	8 yr. 0 mo. to 8 yr. 5 mo.	19405
2 yr. 0 mo. to 2 yr. 5 mo.	13774	8 yr. 6 mo. to 8 yr. 11 mo.	18560
2 yr. 6 mo. to 2 yr. 11 mo.	14264	9 yr. 0 mo. to 9 yr. 5 mo.	18414
3 yr. 0 mo. to 3 yr. 5 mo.	15623	9 yr. 6 mo. to 9 yr. 11 mo.	19654
3 yr. 6 mo. to 3 yr. 11 mo.	15860	10 yr. 0 mo .to 10 yr. 5 mo.	17292
4 yr. 0 mo. to 4 yr. 5 mo.	16528	10 yr. 6 mo. to 10 yr. 11 mo.	17500
4 yr. 6 mo. to 4 yr. 11 mo.	16972	11 yr. 0 mo. to 11 yr. 5 mo.	19833
5 yr. 0 mo. to 5 yr. 5 mo.	17511	11 yr. 6 mo. to 11 yr. 11 mo.	19833
5 yr. 6 mo. to 5 yr. 11 mo.	18178	12 yr. 0 mo. to 12 yr. 5 mo.	16000
6 yr. 0 mo. to 6 yr. 5 mo.	18675	12 yr. 6 mo. to 12 yr. 11 mo.	17000
6 yr. 6 mo. to 6 yr. 11 mo.	18760	13 yr. 0 mo. to 13 yr. 5 mo.	14500
7 yr. 0 mo. to 7 yr. 5 mo.	18977	13 yr. 6 mo. to 13 yr. 11 mo.	
7 yr. 6 mo. to 7 yr. 11 mo.	18939	15 yr. 0 mo. to 15 yr. 5 mo.	15000

These observational means are shown as small circles in figure 31. The ordinates are the pounds of milk produced and the ages are the abscissas. From these observational means the logarithmic curve, shown as the smooth curve of figure 31, is calculated. The equation to this curve is

$$y = 11{,}351.5 + 873.67\,x - 32.225\,x^2 + 1548.36 \operatorname{Log} x$$

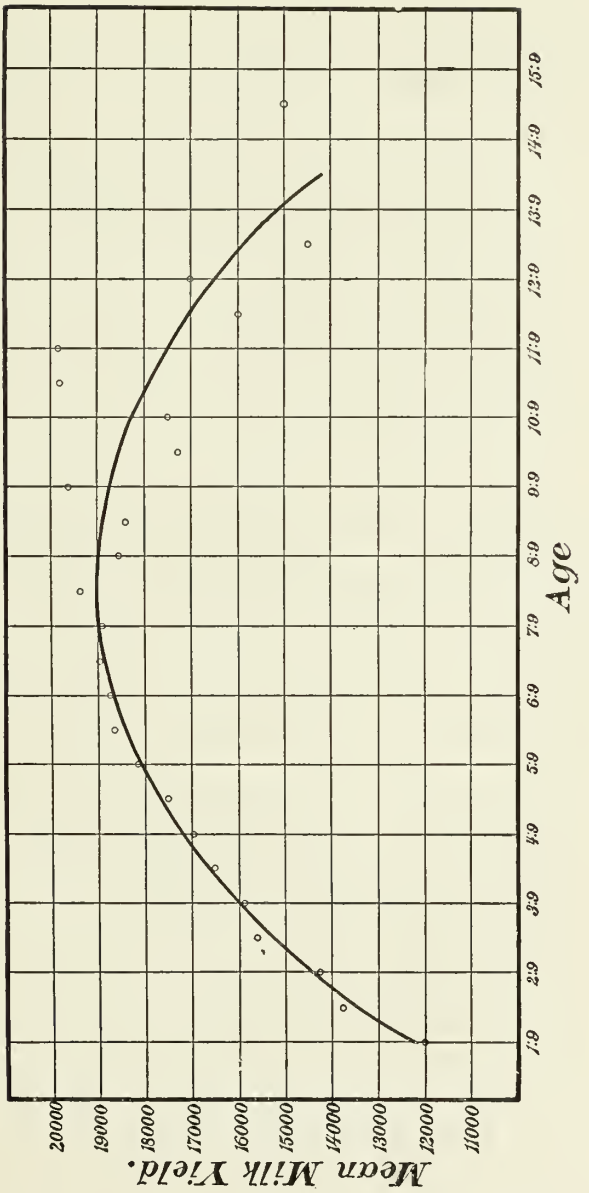

FIG. 31. Observational and fitted curves showing the relation of 365 day milk yield to age for Holstein-Friesian Cattle. The observational curve is represented by small circles. The smooth curve shows the fitted logarithmic curve for milk yield.

TABLE 3.

Correlation Surface Showing the Association of Age and the Butter-Fat Percentage of the 365 Day Record for Holstein-Friesian Cows.

Age at Commencement of Test

Butter-Fat Percentage	1:6–2:0	2:0	2:6	3:0	3:6	4:0	4:6	5:0	5:6	6:0	6:6	7:0	7:6	8:0	8:6	9:0	9:6	10:0	10:6	11:0	11:6	12:0	12:6	13:0	13:6	14:0	14:6	15:0–15:6	
2.3–2.4																													
2.4		1					1																						2
2.5		1										1																	2
2.6			1	2			3									1													7
2.7	1	5	4	2	5	2		2	3		1	1	3	1															30
2.8		8	3	3	6	4	3	4	3	1	2	1	3	2		1	2	1											47
2.9	2	17	6	10	7	6	9	11	1	6	3	1	1	1	2		2	1				1						1	88
3.0	5	30	18	11	17	10	10	9	10	9	8	8	2	7	1	5	1	2			1	1	1					1	167
3.1	4	45	21	22	26	15	19	26	9	16	9	13	7	3	7	2	3	1	1	1		1							251
3.2	4	60	24	10	21	28	24	22	25	15	10	10	4	8	6	5	2	4	2	3		1		1					289
3.3	14	54	43	36	37	22	15	28	23	19	21	18	5	11	12	5	5	2	2		1	1	2						376
3.4	6	60	42	21	33	18	22	15	25	20	14	13	6	11	9	5	5	5	3	2		1							336
3.5	13	59	31	31	22	16	32	20	20	14	15	9	9	6	4	2	4	4	4		2								317
3.6	9	45	31	17	23	16	13	16	13	16	7	2	6	3	4	4		1			1		1						228
3.7	3	45	29	14	10	16	11	9	4	4	3	1	7	4	1	1		2											164
3.8		21	19	10	6	7	8	8	5	7	2	1	1	4	1	4			1										105
3.9	4	7	8	7	8	6	4	6	5	4	4	2	1				1	1						1					69
4.0	4	4	6	3	2	5	5	3	1		4	2									1								40
4.1	1	6	5	1	2	1		3	1	1	1	2	1	1	1		1												28
4.2	1	2	3	1	2			1	1	1		1	1		2														16
4.3		3	2		1	1		2		2				1															12
4.4		2		1		3				1																			7
4.5				1			1	1		1																			4
4.6–4.7				1																									1
	71	475	296	204	228	176	180	186	149	137	104	86	57	63	50	35	26	24	13	6	6	6	4	2				2	2586

It will be noted that this curve strikes through the observations very well. The agreement between the observed and the theoretical curve is especially close for the milk yields of the younger cows. The considerable variation of the older cows in the observational mean curve is due to lack of numbers for the age classes. It will be observed that even here the theoretical curve strikes through the observations well.

By differentiation of the logarithmic equation to the milk yield it is possible to find the age at which the maximum productivity of these cows occurs. This is shown to be 8 years, 4 months and 29 days. While it is true that the change of mean milk yield is slight between the ages 6 years 6 months to 9 years 9 months, still it is equally true that the milk production of these advanced registry cows increase considerably over that given at 5 years. Such an increase is obviously unfair to those cows who are tested at five years in competition with those cows tested at 7 or 8 years.

Table 3 shows the association of 365 day mean butter-fat percentage with age for these same Holstein-Friesian cows. The interval chosen for age is the same as that for the table for milk production and age. The interval for butter-fat percentage is 0.1 of one per cent.

The mean age, the standard deviation and coefficient of variation for age of these cows is of course the same as that of table 1 given on page 189. The mean butter-fat percentage is 3.428; the standard deviation is 0.309. If we compare this coefficient of variation with that for the milk the coefficients are found to stand in the relation of 1 to 2.7. From this it may be argued that butter-fat percentage is much less variable within this group of Holstein-Friesian cows than is the milk yield. This conclusion is in practical agreement with that found for other data comparing milk yield and butter-fat percentage.

The correlation coefficient between butter-fat percentage and yield is $-0.0675 \pm .0133$. The correlation coefficient is consequently slightly significant.

The mean butter-fat percentage for the different age groups as exhibited in table 3 are shown in table 4.

TABLE 4.

Mean 365 Day Butter-Fat Percentage of Holstein-Friesian Cows at Different Ages.

Age at Test	Mean Butter-Fat Percentage	Age at Test	Mean Butter-Fat Percentage
1 yr. 6 mo. to 1 yr. 11 mo.	3.489	8 yr. 0 mo. to 8 yr. 5 mo.	3.399
2 yr. 0 mo. to 2 yr. 5 mo.	3.432	8 yr. 6 mo. to 8 yr. 11 mo.	3.416
2 yr. 6 mo. to 2 yr. 11 mo.	3.483	9 yr. 0 mo. to 9 yr. 5 mo.	3.376
3 yr. 0 mo. to 3 yr. 5 mo.	3.442	9 yr. 6 mo. to 9 yr. 11 mo.	3.342
3 yr. 6 mo. to 3 yr. 11 mo.	3.398	10 yr. 0 mo. to 10 yr. 5 mo.	3.388
4 yr. 0 mo. to 4 yr. 5 mo.	3.449	10 yr. 6 mo. to 10 yr. 11 mo.	3.442
4 yr. 6 mo. to 4 yr. 11 mo.	3.409	11 yr. 0 mo. to 11 yr. 5 mo.	3.300
5 yr. 0 mo. to 5 yr. 5 mo.	3.417	11 yr. 6 mo. to 11 yr. 11 mo.	3.533
5 yr. 6 mo. to 5 yr. 11 mo.	3.410	12 yr. 0 mo. to 12 yr. 5 mo.	3.200
6 yr. 0 mo. to 6 yr. 5 mo.	3.443	12 yr. 6 mo. to 12 yr. 11 mo.	3.350
6 yr. 6 mo. to 6 yr. 11 mo.	3.414	13 yr. 0 mo. to 13 yr. 5 mo.	3.600
7 yr. 0 mo. to 7 yr. 5 mo.	3.366	13 yr. 6 mo. to 13 yr. 11 mo.	
7 yr. 6 mo. to 7 yr. 11 mo.	3.415	15 yr. 0 mo. to 15 yr. 5 mo.	3.000

These observational means are shown as the small circles in figure 32. The ordinates are the percentages of butter-fat and the abscissas are the ages. These observations on butter-fat percentage clearly are linear in their relation to age when the test was made. Such being the case the ordinary regression formula may be used to fit this curve. The equation to this curve is

$$\text{Butter-Fat Percentage} = 3.470 - .009 \text{ age}$$

There is consequently a slight decrease in the butter-fat percentage which a Holstein-Friesian cow is capable of giving as the age of that cow increases. That this increase is slight may be seen from the fact that the decrease in butter-fat percentage from the age of one year and nine months is only 0.130 per cent as shown by the fitted curve of the above figure.

These conclusions concerning the milk yield and the butter-fat percentage make it possible to answer a number of practical questions which are today occupying prominent places in our dairy husbandry. Perhaps one of the most interesting concerns the admission of cows into the advanced registry. In the advanced registry work the linear nature of the butter-fat requirement has already been mentioned. In view of the fact that milk yield in Holstein-Friesian cows is a logarithmic function of age instead of a linear one and that butter-fat percentage has only a slight relation to age it follows that butter-fat is a logarithmic

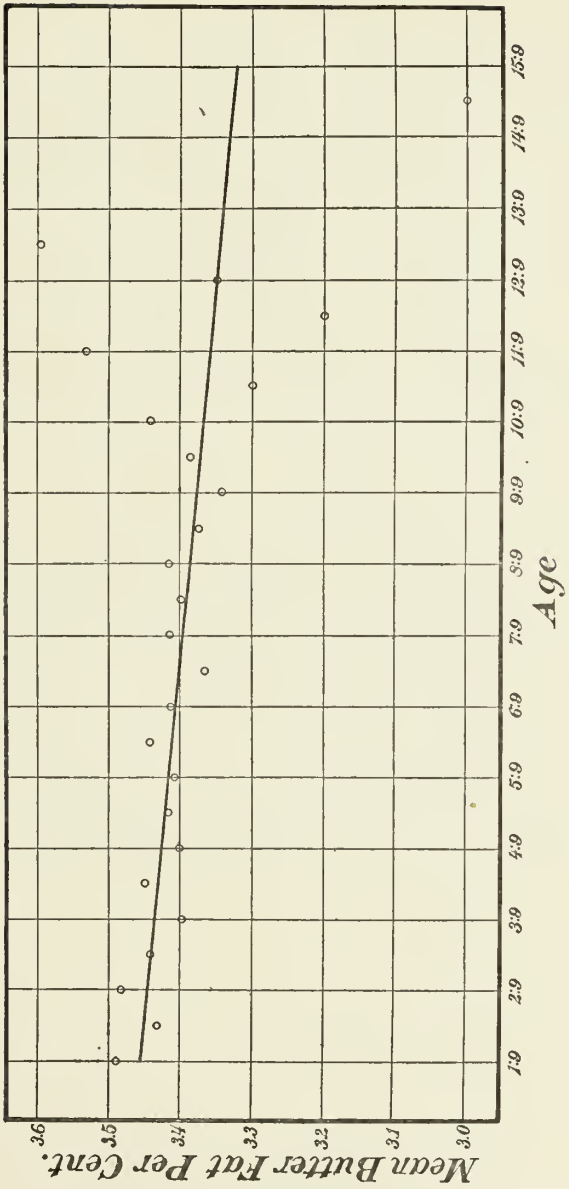

Fig. 32. Observational and fitted curve showing the relation of 365 day Butter-fat percentage to age for Holstein-Friesian Cattle. The observational curve is represented by small circles. The smooth curve shows the fitted line curve for milk yield.

function of age since butter-fat is in truth only the multiple between the milk yield and the butter-fat percentage.

When the calculations are made it is found that the cows commencing their test under 2 years of age are at the greatest handicap. From two years to four years and six months the handicap becomes progressively less. Between four years and six months and five years the handicap is increased by about 1.5 pounds of butter-fat. From five years of age the cow's butter-fat production rises rather rapidly to her maximum yield at about eight years and two months. (This maximum for the butter-fat is somewhat earlier than is the maximum for milk due to the slight decline of the butter-fat percentage with age). From the age of maximum butter-fat production there is a marked decline in the butter-fat as the age of the cow advanced. This decline handicaps the aged cow as compared with one at 7 to 8 years old.

This information allows certain conclusions to be drawn relative to the desirable age at which to commence the advanced registry test for the cow. The most favorable period is between the ages six and one-half years and 9 and one-half years. At this time the average advanced registry cow needs about 80 pounds less butter-fat than she would need as a two year old to make a record sufficient for her to enter into the advanced registry. Other differences are perhaps as striking. At the five year old age the requirement for that age gives the average advanced registry cow about thirty pounds of butter-fat handicap over the cow commencing her test as a two year old.

The Mathematical Handling of Breeding Data.

All investigations and inquiries that involve numbers require more or less mathematical handling. Where the data involved are few an arithmetical mean or average is all that is required. For instance in the chemical analysis of a fertilizer rarely more than two or at the outside three determinations are involved. Hence adding these together and dividing by the number of determinations gives the average. On the other hand in plant and animal breeding work where hundreds or even thousands of units of data are involved the handling involves not merely arithmetical but logarithmic methods also and other problems arise that can only be solved by the calculus.

These data that have to be handled in this complicated way and the results that can only be stated mathematically furnish the only sources for the answer to the questions that confront the practical animal and plant breeder. They must be stated in a mathematical form in order to present the results as they exist. The attempt to put them into everyday language impairs their accuracy of definition. The terms used are new and unusual. For the biometrical methods of handling these data are new. In time these will come to be as readily understood as are the terms used in feeding stuffs and fertilizer analyses.

In its publications of the results of biological investigations the Maine Agricultural Experiment Station is embarrassed by just how far the steps in handling the data upon which the conclusions rest should be printed in the papers designed primarily for the men who are at the fore in the practical agriculture of the State. The bulletins of the Maine Agricultural Experiment Station give in black type at the beginning the conclusions arrived at in the publication. The text gives some of the more obvious and more readily comprehended steps in the investigation. The papers sent to the scientific journals go into the mathematical handling in much more detail.

With the hope of making the matter of the bulletin clear a sort of dictionary of the terms employed has been prepared and will gladly be sent on request to the undersigned.

Chas. D. Woods, Director
Orono, Maine.